TOWARDS A UNIFIED DESCRIPTION OF THE FUNDAMENTAL INTERACTIONS

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Abstract

We consider a recent successful model of leptons as Kerr-Newman type Black Holes in a Quantum Mechanical context. The model leads to a cosmology which predicts an ever expanding accelerating universe with decreasing density and to the conclusion that at Compton wavelength scales, electrons would exhibit low dimensionality, both of which conclusions have been verified by several independent experiments and observations very recently. In this preliminary communication we indicate how the above model describes the quarks' fractional charges, handedness and masses (as any fundamental theory should) and could lead to a unified description of the four fundamental interactions.

1 Introduction

In previous communications[1, 2, 3] a model for leptons as Kerr-Newman type Black Holes was developed, and it was pointed out that several hitherto inexplicable features turned out to have a natural explanation, for example the quantum of charge, the electromagnetic-gravitational interaction ratio, the handedness of the neutrino and so on. We briefly recapitulate some relevant facts.

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As is well known, the Kerr-Newman metric has the electron's anomalous $g = 2$ factor built in, apart from giving the correct field of the particle[4]. In the model referred to, the horizon of the particle Black Hole was taken to be at the Compton wavelength, within which, as is well known, the so called negative energy components χ of the Dirac four spinor dominate. There is ofcourse, in this case, a naked singularity, but this is shielded by Zitterbewegung effects which are symptomatic of the fact, that in Quantum Mechanics we cannot have arbitrarily small space-time intervals unlike in classical theory. It was shown that the fact that, under spatial reflections $\chi \rightarrow -\chi$ while $\phi \rightarrow \phi$ where ϕ represents the positive energy components of the Dirac spinor leads to the emergence of the electromagnetic field owing to the fact that χ shows up as a tensor density of weight $N = 1$, so that its derivative has the following behaviour:

$$\frac{\partial \chi}{\partial x^\mu} \rightarrow \frac{1}{\hbar}[\hbar \frac{\partial}{\partial x^\mu} - NA^\mu]\chi \tag{1}$$

where from (1), we have,

$$A^\mu = \hbar\Gamma^{\mu\sigma}_\sigma = \hbar\frac{\partial}{\partial x^\mu}log(\sqrt{|g|}) \tag{2}$$

It was pointed out that this was how the double valued spin half of Quantum Mechanics could enter a general relativistic formulation. Infact in a linearized theory, we get (cf.ref.[1, 2, 3])

$$g_{\mu v} = \eta_{\mu v} + h_{\mu v}, h_{\mu v} = \int \frac{4T_{\mu v}(t - |\vec{x} - \vec{x}'|, \vec{x}')}{|\vec{x} - \vec{x}'|}d^3x' \tag{3}$$

in the usual notation. As is well known these lead to the relations, in geometrized units[5]

$$m = \int T^{oo}d^3x \tag{4}$$

$$S_k = \int \epsilon_{klm}x^l T^{mo}d^3x \tag{5}$$

It was shown that for the Compton wavelength boundary referred to earlier, one recovers from equation (5) the spin $S_k = \frac{h}{2}$ of the electron while from (3) and (4) we get the usual gravitational potential,

$$\Phi = -\frac{1}{2}(g^{oo} - \eta^{oo}) = -\frac{m}{r} + 0(\frac{1}{r^3}) \tag{6}$$

It was also shown that from equation (2) one could get

$$\frac{ee'}{r} = A_0 \approx \frac{2\hbar G}{r} \int \eta^{\mu\nu} \frac{d}{d\tau} T_{\mu\nu} d^3 x' \qquad (7)$$

where e' is the test charge.

From (7), using (6), we can deduce that (cf.ref.[1] for details),

$$\frac{ee'}{r} = A_0 \approx 2m \int \eta^{ij} \frac{T_{ij}}{r} d^3 x' \qquad (8)$$

whence, as the test charge $e' = e$,

$$e^2 \approx m^2 \qquad (9)$$

or

$$m \sim 10^{-33} cm \qquad (10)$$

which is the Planck mass. In the usual physical units, (9) and (10) become, respectively,

$$e^2 \approx G m^2 \qquad (11)$$

$$m \sim 10^{-5} g \qquad (12)$$

The content of (11) and (12) is that the electromagnetic and gravitational interactions become equal at the Planck mass. For elementary particles with mass $m_p \sim 10^{-20} m$, (11) gives, the well known relation,

$$\frac{e^2}{G m_p^2} \sim 10^{40} \qquad (13)$$

Finally it was also shown that by the usual method, one could consistently get back the Kerr-Newman metric from the above considerations, which was the original inspiration(cf.ref.[6]).

Thus we have a reconciliation between electromagnetism and gravitation. Neutrinos are also described by the above model. In this case as pointed out, because they have vanishingly small mass, they have a very large Compton wavelength so that at our usual spatial scales we encounter predominantly the negative energy components with the peculiar handedness (cf.ref.[1] for details).It was shown in ref.[1] that if on the other hand instead of considering

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distances $>>$ the electron Compton wavelength we consider the distances of the order of the Compton wavelength itself (3) leads to a QCD type potential,

$$4 \int \frac{T_{\mu\nu}(t, \vec{x}')}{|\vec{x} - \vec{x}'|} d^3 x' + (\text{te}rms \quad independent \quad of \quad \vec{x}),$$

$$+2 \int \frac{d^2}{dt^2} T_{\mu\nu}(t, \vec{x}') \cdot |\vec{x} - \vec{x}'| d^3 x' + 0(|\vec{x} - \vec{x}'|^2) \propto -\frac{\propto}{r} + \beta r \qquad (14)$$

The above considerations immediately lead us to consider the possibility of describing weak interactions on the one hand and quarks on the other in the above model.

We will now indicate how it is possible to do so.

2 Strong Interactions

Let us start with the electrostatic potential given in equations (7) and (8). We will first show how the characteristic and puzzling $\frac{1}{3}$ and $\frac{2}{3}$ charges of the quarks emerge.

For this we first note that the electron's spin half which is correctly described in the above model of the Kerr-Newman Black Hole, outside the Compton wavelength automatically implies three spatial dimensions[5, 7]. This is no longer true as we approach the Compton wavelength in which case we deal with low space dimensionality. This indeed has been already observed in experiments with nanotubes[8, 9]. In other words for the Kerr-Newman Fermions spatially confined to distances of the order of their Compton wavelength or less, we actually have to consider two and one spatial dimensionality.

Using now the well known fact[10] that each of the T_{ij} in (7) or (8), is given by $\frac{1}{3}\epsilon$, ϵ being the energy density, it follows from (8) that the particle would have the charge $\frac{2}{3}e$ or $\frac{1}{3}e$, as in the case of quarks. Moreover, as noted earlier (cf.ref.1 also), because we are at the Compton wavelength scale, we encounter predominantly the components χ of the Dirac wave function, with opposite parity. So, as with neutrinos, this would mean that the quarks would display helicity, which indeed is true: As is well known, in the $V - A$ theory, the neutrinos and relativistic quarks are lefthanded while the corresponding antiparticles are right handed (brought out by the small Cabibo angle). This also

automatically implies that these fractionally charged particles cannot be observed individually because they are by their very nature spatially confined. This is also expressed by the confining part of the QCD potential (14). We come to this aspect now.

Let us consider the QCD type potential (14). To facilitate comparison with the standard literature[11], we multiply the left hand expression by $\frac{1}{m}$ (owing to the usual factor $\frac{\hbar^2}{2m}$) and also go over to natural units $c = \hbar = 1$ momentarily. The potential then becomes,

$$\frac{4}{m}\int \frac{T_{\mu v}}{r}d^3x + 2m\int T_{\mu v}rd^3x \equiv -\frac{\propto}{r} + \beta r \tag{15}$$

Owing to (4), $\propto \sim O(1)$ and $\beta \sim O(m^2)$, where m is the mass of the quark. This is indeed the case for the QCD potential (cf.ref.[11]). Interestingly, as a check, one can verify that, as the Compton wavelength distance $r \sim \frac{1}{m}$ (in natural units), the energy given by $(15) \sim O(m)$, as it should be.

Thus both the fractional quark charges (and handedness) and their masses are seen to arise from this formulation.

To proceed further we consider (8) (still remaining in natural units):

$$\frac{e^2}{r} = 2Gm_e\int \eta^{\mu v}\frac{T_{\mu v}}{r}d^3x \tag{16}$$

where at scales greater than the electron Compton wavelength, m_e is the electron mass. At the scale of quarks we have the fractional charge and e^2 goes over to $\frac{e^2}{10} \approx \frac{1}{1370} \sim 10^{-3}$.

So we get from (16)

$$\frac{10^{-3}}{r} = 2Gm_e\int \eta^{\mu v}\frac{T_{\mu v}}{r}d^3x$$

or,

$$\frac{\propto}{r} \sim \frac{1}{r} \approx 2G.10^3 m_e\int \eta^{\mu v}\frac{T_{\mu v}}{r}d^3x$$

Comparison with the QCD potential and (16) shows that the now fractionally charged Kerr-Newman fermion, viz the quark has a mass $\sim 10^3 m_e$, which is correct.

If the scale is such that we do not go into fractional charges, we get from (16), instead, the mass of the intermediary particle as $274m_e$, which is the pion mass.

All this is ofcourse completely consistent with the physics of strong interactions.

3 Weak Interactions

It has already been noted that in the formulation of leptons as Kerr-Newman Black Holes, for Neutrinos, which have vanishingly small mass, if at all, so that their Compton wavelength is infinite or very large, we encounter predominantly the negative energy components of the Dirac spinor. It was shown in, for example, ref.[1], that this explains their characteristic helicity and two component character. One should expect that from the above considerations, we should be able to explain weak interactions also.

Even in the early days leading to the electro-weak theory,[12, 13], it was realized, that with the weak coupling constant set equal to the electromagnetic coupling constant and with a massive intermediary particle $m_w \sim 100 m_p$, where m_p is the proton mass, we get the Fermi local weak coupling constant,

$$G_w = g^2/m_w^2 \approx \frac{10^{-5}}{m_p^2} gm^{-2} \tag{17}$$

This is also the content of our argument: We propose to show now that (17) is consistent with (11), just as at the mass scale of electrons or protons, we get (13) from (11). However, it should be borne in mind that now (11) is not an adhoc experimental result, but rather follows from our model, from equations (1) to (3).

Our starting point is equation (11), which we rewrite, as

$$\frac{e^2 \times 10^{19} \times 10^8}{10^4 m_p^2} \approx \frac{10^{40} \times 10^{19}}{10^4} \approx 10^{55},$$

remembering that $G \sim 10^{-8}$ and $e^2 \sim 10^{-19}$. From here we get,

$$\frac{g^2}{m_w^2} \approx 10^{43} gm^{-2}$$

with $g^2 \approx 10^{-1}$ and $m_w \approx 100 m_p$ which is consistent with (17).

4 Discussion and Conclusion

The model of leptons as Kerr-Newman Black Holes, as discussed in Section 1 leads to a cosmology[2, 14, 15] in which the universe continues to expand

and accelerate with ever decreasing density. Interestingly this has been confirmed by several independent recent observations[16, 17, 18]. On the other hand the model also predicts that near Compton wavelength scales electrons would display a neutrino type bosonization or low dimensionality[19]. As pointed out earlier (cf.refs.[8, 9]), this has been confirmed in the case of recently developed carbon nanotubes.

What we have shown above is that the Kerr-Newman Black Hole description of the electron leads to a unification of gravitation and electromagnetism as expressed by (11) or (13). It also gives a clue to the peculiar fractional charges and also masses of the quarks and the QCD interaction, as expressed by (15). Finally the model explains the handedness of the neutrino and gives a clue to the origin of weak interactions, as expressed by (17).

So at the heart of the matter is the description of the electron as a Kerr-Newman Black Hole, valid at length scales greater than the Compton wavelength. The other phenomena appear from here at different length (or energy) scales.

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